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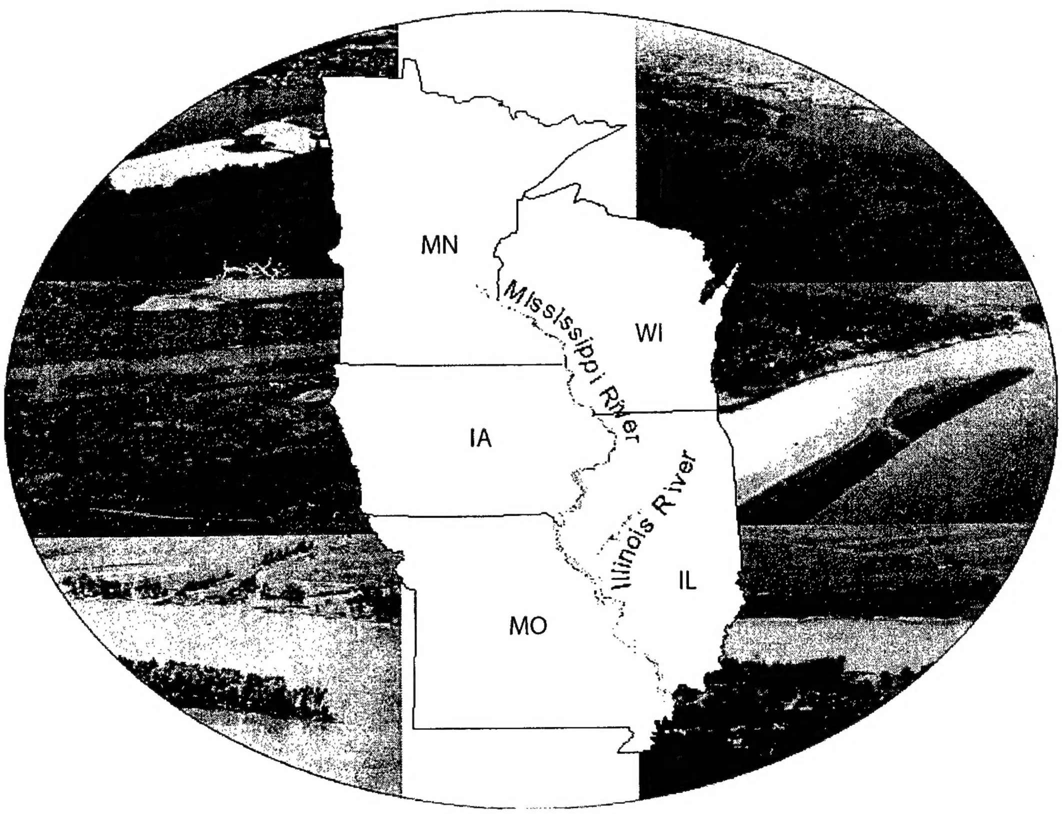
Technical Report
2005-T002

Spatial, Temporal, and Environmental Trends of Fish Assemblages within Six Reaches of the Upper Mississippi River System



February 2005

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Contents

Tables

Figures

Number *Page*

Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Upper Midwest Environmental Sciences Center, a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Program responsibility. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its multiple-use character. The long-term goals of the Program are to understand the system, determine resource trends and effects, develop management alternatives, manage information, and develop useful products.

This multiyear report supports Tasks 2.2.8 and 2.3.2 as specified in Goal 2, *Monitor Resource Change*, of the LTRMP Operating Plan (U.S. Fish and Wildlife Service 1993). This report was developed with funding provided by the LTRMP.

Spatial, Temporal, and Environmental Trends of Fish Assemblages within Six Reaches of the Upper Mississippi River System

by

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Abstract: We investigated differences in adult and young-of-the-year (YOY) fishes within each of the six Long Term Resource Monitoring Program study areas, using monitoring data from 1993 to 2001. Our objective was to investigate the relative roles of seasonal, annual, in situ, and physical habitat factors in explaining assemblage structure patterns within the Long Term Resource Monitoring Program study areas. Adult and YOY assemblage structure within each reach was dominated by one to three numerically abundant species. The percent of the total abundance for which these species accounted was 10–88% and varied among age classes and study areas. Physical habitat classes were only weakly associated with differences in fish assemblage patterns within each study area. The amount of variation in fish abundance explained by physical habitats varied among the reaches. Differences among physical habitat classes accounted for 3–23% of the variation in the adult fish assemblage and for 3–20% of the difference in the YOY fish assemblage within each reach of our study area. Factors associated with interannual differences in environmental conditions were strongly correlated to patterns in assemblage structure within each of the six study areas. This was particularly true for YOY assemblages. Such a result would not have been attainable without long-term standardized data. Little is known regarding YOY assemblage patterns and dynamics in large river systems and long-term data sets are vital for continued investigation. The influence of environmental gradients on fish assemblage structure varied among the six study areas and explained 9–31% of the variation in assemblage structure. In the northern four reaches, water velocity was one of the primary factors associated with differences in fish assemblage structure. In the Unimpounded Reach (Upper Mississippi River) and Illinois River study areas, river elevation was one of the primary factors associated with differences in assemblage structure. Depth of gear deployment was influential in explaining differences in assemblage structure patterns in all reaches except the Upper Mississippi River Pool 4 and the Illinois River study areas. In all study areas, the amount of variation in fish abundance patterns explained by sampling period was relatively low. However, assemblage structure differed among sampling periods. In the northern reaches, sampling periods 2 and 3 were the most similar.

Key words: fishes; Illinois River, impounded, long-term, LTRMP, Mississippi River, ordination, unimpounded, YOY

Introduction

Large river systems worldwide have been subjected to anthropogenic disturbances throughout the last century (Petts et al. 1989; Dynesius and Nilsson 1994). These changes include channelization, the creation of wing dikes and levees, dredging, loss of low velocity physical habitats, exotic species introductions, agricultural pollution, and the creation of locks and dams (Gehrke et al. 1995; Williams et al. 1996). As a result, North America's temperate

freshwater ecosystems are being depleted of species as rapidly as tropical forests (Ricciardi and Rasmussen 1999), and this loss has been exacerbated by landscape-level disturbances (i.e., erosion, sedimentation, river regulation, degraded water quality, etc.).

Natural floodplain rivers are among the most biologically productive and diverse ecosystems (Tockner and Standforth 2002). They are also among the most disturbed ecosystems, especially in north temperate regions (Welcomme 1979). Large floodplain rivers are generally regarded as having diverse physical habitat maintained by natural flows, providing the variety of lentic and lotic environments that support diverse fish faunas (Poff et al. 1997). This diversity, both biological and physical, may exist because of the channel-floodplain complex and the annual cycle of flooding (i.e., flood-pulse concept; Junk et al. 1989). Whereas the flood-pulse concept has yet to be validated in large temperate rivers, studies in Europe (Welcomme 1995) and North America (Hesse et al. 1993) indicate similar processes between temperate and tropical rivers. River-floodplain connectivity and habitat heterogeneity are maintained by natural hydrologic regimes and environmental gradients (Sparks et al. 1990; Ward 1998). However, altered hydrologic regimes, habitat modifications, exotic species invasions, and pollution are resulting in floodplain degradation and may prove to lower species diversity (Heiler et al. 1995; Theiling 1996; Pegg and Pierce 2002).

The Upper Mississippi River System (UMRS) is probably the most biologically productive and economically important large floodplain river system in the United States (Patrick 1998; U.S. Geological Survey 1999). Fishes inhabiting the UMRS occupy a broad range of macrohabitats, including the navigation channel (Dettmers et al. 2001). However, fish:habitat relations and assemblages across environmental gradients are just beginning to be explored (Pegg and Pierce 2001, 2002; Braaten and Guy 2002; Barko and Herzog 2003; Barko et al. 2004*b*).

Whereas a wealth of biological data is available on the Mississippi River (Patrick 1998), most studies conducted were largely area specific and not standardized. As navigation expanded on the UMRS, concerns grew over the sustainability of the ecosystem. Consequently, the Environmental Management Program was created in 1986 in response to these concerns (Lubinski 1999). The Environmental Management Program includes a biological monitoring program for the UMRS known as the Long Term Resource Monitoring Program (LTRMP; Jackson et al. 1981; U.S. Fish and Wildlife Service 1993). Although the state of Illinois has maintained a longer Illinois River monitoring program (Bertrand 1997), the LTRMP is the largest systemic monitoring program in the basin. Understanding how fish assemblages are similar or different within the LTRMP study areas is critical for evaluating past and present stressors on fish resources throughout the UMRS, while understanding how assemblages respond to ecosystem changes over time is critically important for adaptive management of the UMRS.

Using LTRMP data, we investigated fish assemblages within five reaches of the UMR and one reach of the Illinois River to better understand patterns in assemblage structure and identify trends. The objectives of this study were to assess associations between fish species abundance, sampling periods, sampling years, environmental variables, and five physical habitat classes using ordination techniques.

Materials and Methods

Field Methods

We used data collected from 1993 to 2001 in five reaches of the UMR and one reach of the Illinois River (La Grange Pool; river mile [RM] 80–158) by the LTRMP (Gutreuter et al. 1995). Mississippi River study areas included Pool 4 (excluding Lake Pepin; RM 752–797), Pool 8 (RM 679–703), Pool 13 (RM 523–557), Pool 26 (RM 202–242), and the Unimpounded Reach (RM 29–80; Figure 1). Fishes were sampled annually from June 15 to October 30 in three annual sampling periods (1: June 15–July 31; 2: August 1–September 15; 3: September 16–October 30) using a stratified random sampling design developed by Gutreuter et al. (1995). At each site, measurements of water temperature,

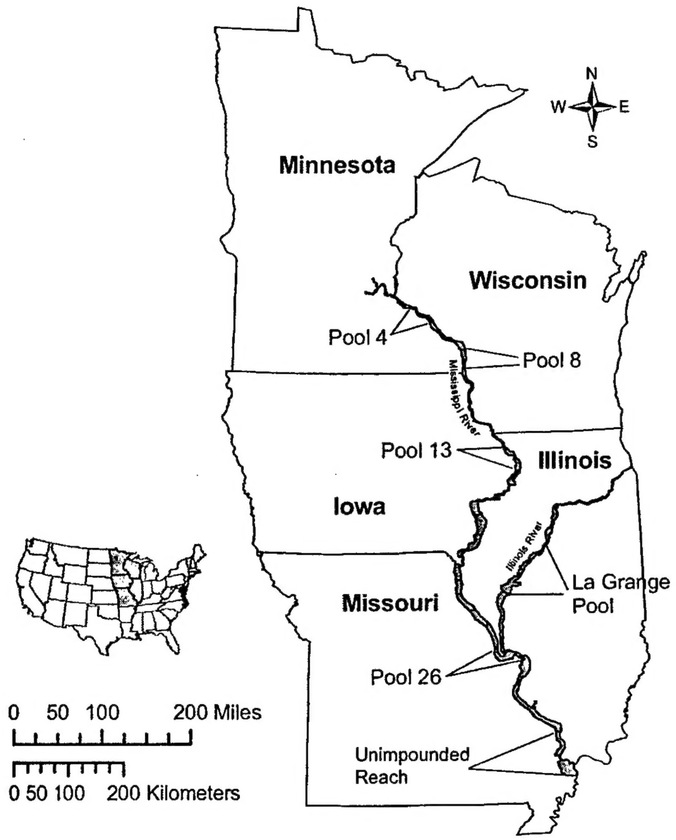


Figure 1. Geographic representation of the six Upper Mississippi River System Long Term Resource Monitoring Program sites sampled from 1993 to 2001.

Secchi transparency, depth of gear deployment, water velocity, and conductivity were made prior to fish sampling. Water temperature was measured to the nearest 0.1°C and conductivity was measured in µS/cm using a Labcomp digital conductivity meter. A Marsh-McBirney flow meter (model 201 D; Frederick, MD) was used to measure water velocity to the nearest 0.01 m/s. Depth of gear deployment was measured to the nearest 0.1 m using boat-mounted sonar. River elevation was obtained from the U.S. Geological Survey for each day of sampling.

Data collected from five physical habitat classes and four sampling gears common to all six study areas were used for analysis. Physical habitat was classified and stratified based on geomorphic features and included side channel border, backwater contiguous, main channel border, main channel border wing dike, and impounded (Gutreuter et al. 1995). Collection methods included active (daytime electrofishing) and passive (mini-fyke netting, small and large hoop netting) techniques. See Gutreuter et al. (1997*a–c*) and Burkhardt et al. (1997, 1998, 2000, 2001, 2004*a,b*) for annual gear allocations within and among the six study areas.

Statistical Methods—Ordination

We separated young-of-the-year (YOY) fishes from adult fishes using reported lengths for each species (Carlander 1969, 1977; Becker 1983; Etnier and Starnes 1993; Morrow and Kirk 1995; Pflieger 1997; Gido et al. 2000) following the methodology of Barko et al. (2004*a*) because adult and YOY fishes appear to exhibit different responses to physical habitats and environmental conditions in this system (Barko and Herzog 2003; Barko et al. 2004*a,b*). Hybrid individuals, larval fishes, and unidentified fishes were removed from the data set prior to analysis. We conducted separate ordination analyses for each study area, using all four gears combined, to enable us to identify reach-related trends and determine whether the fish assemblages responded similarly to environmental and temporal variability. Ordination methods used in analysis included detrended correspondence (DCA), canonical correspondence (CCA), partial canonical correspondence (pCCA), and stepwise pCCA, with methodology following Barko et al. (2004*b*). All analyses were performed using CANOCO v. 4.5 (ter Braak and Šmilauer 2002). An estimate of the amount of variation explained by each ordination analysis is provided by the sum of all canonical eigenvalues (Lepš and Šmilauer 2003). Caution must be used in interpretation, however, because the amount of variation explained is not equivalent to an r^2 value. For visual clarity, we only display abundant taxa (e.g., species weights ≥1) on ordination biplots by species codes listed in Table 1. Discussions on biplot interpretation can

Table 1. Abundance of each fish species (adult/young-of-the-year) collected by the Long Term Resource Monitoring Program in the Upper Mississippi River System from 1993 to 2001 using daytime electrofishing, mini-fyke netting, and small and large hoop netting. Numerically dominant species (>10% of total catch) are in bold by reach.

Family name	Common name-species code	Scientific name	Pool 4	Pool 8	Pool 13	Pool 26	Illinois River	Unimpounded
Petromyzontidae	Chestnut lamprey-CNLP	*Ichthyomyzon castaneus*	6/0	33/3	3/0	3/0	1/0	23/3
	Silver lamprey-SVLP	*Ichthyomyzon unicuspis*	11/1	53/0	12/0	2/0	0/0	0/0
	American brook lamprey-ABLP	*Lampetra appendix*	2/0	0/0	0/0	0/0	0/0	0/0
Acipenseridae	Lake sturgeon-LKSG	*Acipenser fulvescens*	1/0	0/0	0/0	0/0	0/0	0/0
	Shovelnose sturgeon-SNSG	*Scaphirhynchus platorynchus*	0/0	2/0	12/0	1/0	0/0	8/3
Polyodontidae	Paddlefish-PDFH	*Polyodon spathula*	0/0	0/0	0/0	2/0	0/0	1/1
Lepisosteidae	Spotted gar-STGR	*Lepisosteus oculatus*	0/0	0/0	1/0	36/6	12/2	4/0
	Longnose gar-LNGR	*Lepisosteus osseus*	13/16	127/142	46/30	17/21	35/15	20/42
	Shortnose gar-SNGR	*Lepisosteus platostomus*	11/2	242/33	242/78	938/148	201/29	492/27
Amiidae	Bowfin-BWFN	*Amia calva*	141/0	177/3	153/5	36/0	28/0	18/0
Hiodontidae	Goldeye-GDEY	*Hiodon alosoides*	0/0	0/0	1/0	25/140	11/14	29/1,416
	Mooneye-MNEY	*Hiodon tergisus*	59/1	44/6	23/25	13/58	0/0	4/46
Anguillidae	American eel-AMEL	*Anguilla rostrata*	4/0	0/0	0/0	3/0	1/0	13/0
Clupeidae	Skipjack herring-SJHR	*Alosa chrysochloris*	0/1	0/0	0/0	225/137	532/1.093	62/74
	Gizzard shad-GZSD	***Dorosoma cepedianum***	**4,950/4,822**	4,802/4,295	**5,189/9,889**	**17,121/34,384**	**16,449/88,245**	**6,744/11,122**
	Threadfin shad-TFSD	*Dorosoma petenense*	0/0	0/0	0/0	64/183	617/883	207/106
Cyprinidae	Central stoneroller-CLSR	*Campostoma anomalum*	0/0	0/0	1/0	0/11	1/1	4/7
	Goldfish-GDFH	*Carassius auratus*	0/0	0/0	0/0	5/1	35/38	2/0
	Grass carp-GSCP	*Ctenopharyngodon idella*	0/0	0/0	0/0	24/38	121/63	9/3
	Red shiner-RDSN	*Cyprinella lutrensis*	0/0	0/0	0/0	243/54	118/6	1.961/132
	Spotfin shiner-SFSN	*Cyprinella spiloptera*	1.282/1.179	**9,487/11,105**	959/293	472/2.616	0/0	10/1
	Blacktail shiner-BTSN	*Cyprinella venusta*	0/0	0/0	0/0	0/0	0/0	36/0
	Common carp-CARP	*Cyprinus carpio*	3,751/92	3,972/1,820	4,249/1,277	**12,969/257**	**11,007/373**	3,777/461
	Western silvery minnow-WSMW	*Hybognathus argyritis*	0/0	0/0	0/0	7/0	0/0	0/0
	Brassy minnow-BSMW	*Hybognathus hankinsoni*	0/0	1/1	0/0	0/0	0/0	0/0
	Mississippi silvery minnow-SVMW	*Hybognathus nuchalis*	0/0	2/14	9/1	74/137	0/0	25/202
	Plains minnow-PNMW	*Hybognathus placitus*	0/0	0/0	0/0	0/0	0/0	1/2
	Silver carp-SVCP	*Hypophthalmichthys molitrix*	0/0	0/0	0/0	15/0	57/7	0/14
	Bighead carp-BHCP	*Hypophthalmichthys nobilis*	0/0	0/0	0/0	113/8	52/69	6/42
	Striped shiner-SPSN	*Luxilus chrysocephalus*	0/0	0/0	0/0	0/0	0/0	1/0
	Speckled chub-SKCB	*Macrhybopsis aestivalis*	1/0	0/0	2/0	4/4	0/0	57/32
	Silver chub-SVCB	*Macrhybopsis storeriana*	38/1	33/0	229/104	115/76	54/16	37/64

Table 1. Continued.

Family name	Common name-species code	Scientific name	Pool 4	Pool 8	Pool 13	Pool 26	Illinois River	Unimpounded
	Golden shiner-GDSN	*Notemigonus crysoleucas*	19/45	79/806	95/887	0/27	18/102	1/0
	Emerald shiner-ERSN	***Notropis atherinoides***	**10,148/33,720**	6,606/9,**184**	**10,190**/7,450	6,454/6,385	3,437/1,295	2,381/759
	River shiner-RVSN	*Notropis blennius*	620/3	2,880/1,790	2,700/6,686	683/1,105	0/2	65/50
	Bigeye shiner-BESN	*Notropis boops*	0/0	0/0	0/0	1/4	0/0	3/0
	Ghost shiner-GTSN	*Notropis buchanani*	0/0	0/0	0/0	0/1	0/0	0/0
	Spottail shiner-STSN	*Notropis hudsonius*	289/2	600/185	539/120	14/13	20/2	1/0
	Silverband shiner-SBSN	*Notropis shumardi*	0/0	0/0	0/0	102/285	73/3	398/319
	Sand shiner-SNSN	*Notropis stramineus*	3/16	2/13	0/3	3/38	0/0	0/1
	Weed shiner-WDSN	*Notropis texanus*	15/1	1398/470	0/0	0/0	0/0	0/0
	Mimic shiner-MMSN	*Notropis volucellus*	34/1,221	1,002/3,062	120/**3,5679**	0/0	0/0	1/12
	Channel shiner-CNSN	*Notropis wickliffi*	0/0	0/0	49/2,584	52/**8,481**	0/0	272/**4,270**
	Pugnose minnow-PGMW	*Opsopoeodus emiliae*	110/682	1,257/4,002	84/142	0/0	0/0	0/2
	Suckermouth minnow-SMMW	*Phenacobius mirabilis*	0/0	0/0	0/1	4/4	0/1	0/0
	Southern redbelly dace-SRBD	*Phoxinus erythrogaster*	0/0	0/0	0/2	0/0	0/0	0/0
	Bluntnose minnow-BNMW	*Pimephales notatus*	12/24	4/6	3/58	4/16	6/4	5/27
	Fathead minnow-FHMW	*Pimephales promelas*	7/0	37/2	8/21	0/0	1/0	1/0
	Bullhead minnow-BHMW	*Pimephales vigilax*	1,177/365	**9,868**/3,167	2,099/293	1,424/301	191/15	63/18
	Creek chub-CKCB	*Semotilus atromaculatus*	0/0	0/0	0/0	1/1	0/9	0/1
Catostomidae	River carpsucker-RVCS	*Carpiodes carpio*	59/1	54/4	305/1,374	387/208	457/85	550/384
	Quillback-QLBK	*Carpiodes cyprinus*	187/130	45/707	26/34	2/20	4/6	2/5
	Highfin carpsucker-HFCS	*Carpiodes velifer*	0/0	2/0	101/0	0/0	8/0	0/0
	White sucker-WTSK	*Catostomus commersoni*	37/3	3/6	4/0	0/1	0/0	0/0
	Blue sucker-BUSK	*Cycleptus elongatus*	16/0	14/5	4/0	8/4	0/0	16/16
	Northern hog sucker-NHSK	*Hypentelium nigricans*	1/0	5/0	2/0	0/0	2/0	0/0
	Smallmouth buffalo-SMBF	*Ictiobus bubalus*	393/2	962/231	1,760/26	3,863/256	4,166/170	1,259/4
	Bigmouth buffalo-BMBF	*Ictiobus cyprinellus*	51/10	41/19	160/13	352/138	3,043/145	166/125
	Black buffalo-BKBF	*Ictiobus niger*	0/0	0/0	11/0	276/2	239/1	312/13
	Spotted sucker-SPSK	*Minytrema melanops*	404/3	724/48	241/0	0/0	0/0	0/0
	Silver redhorse-SVRH	*Moxostoma anisurum*	1,009/12	1,783/127	18/2	0/0	6/0	0/0
	River redhorse-RVRH	*Moxostoma carinatum*	308/0	239/0	0/0	0/0	0/0	2/0
	Golden redhorse-GDRH	*Moxostoma erythrurum*	325/3	925/9	31/2	7/5	26/2	1/2
	Shorthead redhorse-SHRH	*Moxostoma macrolepidotum*	1,504/175	3,855/569	588/126	113/10	191/37	8/0
Ictaluridae	Black bullhead-BKBH	*Ameiurus melas*	1/0	8/0	32/14	26/0	40/6	4/0

Table 1. Continued.

Family name	Common name-species code	Scientific name	Pool 4	Pool 8	Pool 13	Pool 26	Illinois River	Unimpounded
	Yellow bullhead-YLBH	*Ameiurus natalis*	3/0	12/0	48/1	10/3	91/2	1/4
	Brown bullhead-BNBH	*Ameiurus nebulosus*	0/0	3/4	0/0	11/0	23/1	0/0
	Blue catfish-BLCF	*Ictalurus furcatus*	0/0	0/0	0/0	462/7	0/0	183/18
	Channel catfish-CNCF	*Ictalurus punctatus*	271/2	2,725/9	1,787/39	7,837/301	1,576/44	**3,924**/595
	Stonecat-STCT	*Noturus flavus*	1/0	2/2	4/6	2/0	1/0	1/5
	Tadpole madtom-TPMT	*Noturus gyrinus*	10/1	84/80	123/69	3/2	1/3	1/0
	Freckled madtom-FKMT	*Noturus nocturnus*	0/0	0/0	0/0	5/0	0/0	37/24
	Flathead catfish-FHCF	*Pylodictis olivaris*	65/1	217/29	199/2	578/2	216/0	580/17
Esocidae	Grass pickerel-GSPK	*Esox americanus vermiculatus*	0/0	0/0	0/1	0/3	1/8	0/0
	Northern pike-NTPK	*Esox lucius*	161/45	180/113	39/19	1/0	0/0	0/0
Umbridae	Central mudminnow-CMMW	*Umbra limi*	0/0	8/8	0/12	0/0	0/0	0/0
Salmonidae	Brown trout-BNTT	*Salmo trutta*	0/0	0/1	0/0	0/0	0/0	0/0
Percopsidae	Trout-perch-TTPH	*Percopsis omiscomaycus*	7/2	6/2	0/0	0/0	0/0	0/0
Aphredoderidae	Pirate perch-PRPH	*Aphredoderus sayanus*	0/0	2/1	0/0	2/2	2/3	1/3
Gadidae	Burbot-BRBT	*Lota lota*	3/3	11/5	0/0	0/0	0/0	0/0
Fundulidae	Starhead topminnow-SHTM	*Fundulus dispar*	0/0	0/0	0/0	1/0	0/0	0/0
	Blackstripe topminnow-BTTM	*Fundulus notatus*	0/0	0/0	0/0	7/0	25/1	14/1
	Blackspotted topminnow-BPTM	*Fundulus olivaceus*	0/0	0/0	0/0	0/0	0/0	3/0
Poeciliidae	Western mosquitofish-MQTF	*Gambusia affinis*	0/0	0/0	0/0	1,170/6,573	36/34	76/23
Atherinidae	Brook silverside-BKSS	*Labidesthes sicculus*	5/29	146/253	52/1,170	28/39	20/89	58/80
	Inland silverside-IDSS	*Menidia beryllina*	0/0	0/0	0/0	0/0	0/0	17/0
Gasterosteidae	Brook stickleback-BKSB	*Culaea inconstans*	0/0	5/6	2/0	0/0	0/0	0/0
Percichthyidae	White perch-WTPH	*Morone americana*	0/0	0/0	0/0	0/0	5/8	0/0
	White bass-WTBS	*Morone chrysops*	446/930	234/1,519	194/2,403	546/3,090	1,235/4,286	286/784
	Yellow bass-YWBS	*Morone mississippiensis*	0/0	0/6	7/28	2/21	11/83	2/4
	Striped bass-SDBS	*Morone saxatilis*	0/0	0/0	0/0	0/0	3/0	0/3
Centrarchidae	Rock bass-RKBS	*Ambloplites rupestris*	620/4	1,222/34	45/0	0/0	0/0	0/0
	Green sunfish-GNSF	*Lepomis cyanellus*	53/0	717/38	9/0	302/1	157/2	146/3
	Pumpkinseed-PNSD	*Lepomis gibbosus*	67/0	345/111	721/425	0/0	1/0	0/0
	Warmouth-WRMH	*Lepomis gulosus*	0/0	62/23	78/21	79/40	131/24	6/35
	Orangespotted sunfish-OSSF	*Lepomis humilis*	4/0	1,200/64	2,336/530	2,480/354	220/1	174/15
	Bluegill-BLGL	***Lepomis macrochirus***	**4,588**/283	**24,868**/291	**20,023**/3,191	5,144/338	**7,547**/558	1,266/531
	Longear sunfish-LESF	*Lepomis megalotis*	0/0	0/0	0/0	0/0	13/0	8/9

Table 1. Continued.

Family name	Common name-species code	Scientific name	Pool 4	Pool 8	Pool 13	Pool 26	Illinois River	Unimpounded
	Redear sunfish-RESF	*Lepomis microlophus*	0/0	0/0	0/0	1/0	7/0	0/0
	Smallmouth bass-SMBS	*Micropterus dolomieu*	1,316/7	2,302/33	81/0	4/0	1/0	1/0
	Spotted bass-STBS	*Micropterus punctulatus*	0/0	0/0	0/0	0/0	0/0	66/10
	Largemouth bass-LMBS	*Micropterus salmoides*	1,755/0	5,487/304	3,345/1,558	683/33	2,615/1	20/1
	White crappie-WTCP	*Pomoxis annularis*	79/23	81/11	571/234	198/97	893/43	204/239
	Black crappie-BKCP	*Pomoxis nigromaculatus*	633/76	1,709/415	1,040/167	499/154	1,569/22	148/58
Percidae	Crystal darter-CLDR	*Ammocrypta asprella*	0/3	0/0	0/0	0/0	0/0	0/0
	Western sand darter-WSDR	*Ammocrypta clara*	0/1	15/10	0/0	0/0	0/0	0/0
	Mud darter-MDDR	*Etheostoma asprigene*	4/4	70/140	52/139	1/8	21/5	2/6
	Bluntnose darter-BNDR	*Etheostoma chlorosomum*	0/0	0/0	3/0	0/0	0/0	4/0
	Iowa darter-IODR	*Etheostoma exile*	0/0	5/3	0/0	0/0	0/0	0/0
	Fantail darter-FTDR	*Etheostoma flabellare*	0/0	1/0	0/0	0/0	0/0	0/0
	Johnny darter-JYDR	*Etheostoma nigrum*	68/22	736/623	131/203	0/0	0/4	1/0
	Orangethroat darter-OTDR	*Etheostoma spectabile*	0/0	0/0	0/0	0/0	0/0	2/0
	Banded darter-BDDR	*Etheostoma zonale*	1/0	1/0	0/0	0/0	0/0	0/0
	Yellow perch-YWPH	*Perca flavescens*	943/77	615/236	104/19	0/0	0/0	0/0
	Logperch-LGPH	*Percina caprodes*	157/286	540/1,000	142/241	28/24	22/49	0/15
	Blackside darter-BSDR	*Percina maculata*	0/0	3/0	0/0	0/0	0/0	0/0
	Slenderhead darter-SHDR	*Percina phoxocephala*	3/3	52/55	3/1	10/2	2/4	2/1
	Dusky darter-DYDR	*Percina sciera*	0/0	0/0	0/0	0/0	0/0	0/1
	River darter-RRDR	*Percina shumardi*	3/17	11/98	11/554	5/61	0/0	0/11
	Sauger-SGER	*Stizostedion canadense*	352/151	517/214	390/116	179/146	363/209	38/69
	Walleye-WLYE	*Stizostedion vitreum*	224/199	193/191	77/207	3/9	3/3	1/3
Sciaenidae	Freshwater drum-FWDM	*Aplodinotus grunniens*	654/92	1,002/1,018	1,095/7,448	2,191/3,711	1,891/1,802	1,219/12,828
Total			39,495/44,794	96,757/48,784	63,013/86,023	68,775/70,605	59,662/100,028	27,554/35,204

be found in Legendre and Legendre (1998) or Lepš and Šmilauer (2003).

Results and Discussion

Assemblage Structure

In all four gears combined, we collected 740,994 fishes comprising 122 species in 7,838 sampling episodes (i.e., Pool 4 = 714, Pool 8 = 1,885, Pool 13 = 1,546, Pool 26 = 1,701, Unimpounded Reach = 1,206, and Illinois River = 786; Table 1). Pool 8 had the most adult fish (67% of total catch), followed by Pool 26 (49%), Pool 4 (47%), Unimpounded Reach (44%), Pool 13 (42%), and the Illinois River reach (38%). The numerically abundant component of the adult and YOY assemblage (e.g., species accounting for >10% of total catch) differed among the age classes and reaches. In Pool 4, there were three numerically abundant adult species, emerald shiner (*Notropis atherinoides*; 26%), gizzard shad (*Dorosoma cepedianum*; 13%), and bluegill (*Lepomis macrochirus*; 12%), which accounted for 51% of the total adult abundance. Emerald shiner and gizzard shad comprised 86% of the YOY abundance (75% and 11%, respectively). In Pool 8, there were two numerically abundant adult species, bluegill (26%) and bullhead minnow (*Pimephales vigilax*; 10%), and two numerically abundant YOY species, emerald shiner (19%) and spotfin shiner (*Cyprinella spiloptera*; 23%). In Pool 13, there were also two numerically abundant adult species, bluegill (32%) and emerald shiner (16%), and two YOY species, gizzard shad (12%) and mimic shiner (*Notropis volucellus*; 41%). The numerically abundant component of the adult assemblage were gizzard shad (25%), common carp (*Cyprinus carpio*; 19%), and channel catfish (*Ictalurus punctatus*; 11%), whereas the numerically abundant component of the YOY assemblage were gizzard shad (49%) and channel shiner (*Notropis wickliffi*; 12%). Gizzard shad (25%) and channel catfish (14%) were the numerically abundant fishes of the Unimpounded Reach adult assemblage whereas freshwater drum (*Aplodinotus grunniens*; 36%), gizzard shad (32%), and channel shiner (12%) were the numerically abundant fishes of the YOY assemblage. Gizzard shad (27%), common carp (18%), and bluegill (13%) were the numerically abundant adult species in the Illinois River, whereas gizzard shad alone accounted for 88% of the YOY abundance. Of the 10 numerically abundant species listed above, 7 (emerald shiner, gizzard shad, bluegill, bullhead minnow, common carp, channel catfish, and freshwater drum) are considered fluvial generalists (Kingsolving and Bain 1993; Galat et al. *In press*; Barko et al. 2004*b*). Collectively, these seven fluvial generalists accounted for 64% of the total UMR fish abundance. The remaining three species are considered fluvial specialists (Barko et al. 2004*b*).

Ordination—Environmental Gradients/fish Assemblages

The six environmental variables measured concurrently with fish sampling (Table 2) had varied effects on fish assemblages. These variables explained 23% of the variation in fish abundance in Pool 4, 23% of the variation in fish abundance in Pool 8, 17% of the variation in fish abundance in Pool 13, 31% of the variation in fish abundance in Pool 26, 30% of the variation in fish abundance in the Unimpounded Reach, and 9% of the variation in fish abundance in the Illinois River reach (Table 3). Because of shared variance among the variables, percentages listed in Table 3 may not sum to equal the overall percentages listed above. Water velocity was one of the primary factors (i.e., explained the most variation and had the longest arrow[s] on the ordination biplots) associated with differences in fish assemblage structure in the northern four study areas (Figure 2). In the Unimpounded Reach and the Illinois River reach, river elevation was one of the primary factors associated with differences in fish assemblage structure (Figure 2). Depth of gear deployment was influential in explaining differences in assemblage structure patterns in all study areas except Pool 4 and the Illinois River (Figure 2). Secchi transparency was most influential in Pool 4, whereas conductivity was most influential in the Illinois River reach (Figure 2).

Table 2. Summary statistics and number of samples (*N*) for environmental variables measured during fish sampling in the Upper Mississippi River System from 1993 to 2001 at six sampling reaches (see Figure 1).

Field station	*N*	Secchi (cm)				Water temperature (°C)				Water depth (m)			
		Min	Max	Mean	Std	Min	Max	Mean	Std	Min	Max	Mean	Std
Illinois River	786	5	80	21	10	7.5	35.0	23.9	5.0	0.3	11.0	1.1	0.8
Unimpounded Upper Mississippi River	1,206	1	69	24	12	7.9	31.9	24.9	4.5	0.1	16.5	2.1	1.7
Pool 26	1,701	7	85	33	14	10.8	54.1	24.9	5.6	0.1	18.7	2.3	2.3
Pool 13	1,546	8	120	37	13	7.2	33.0	22.9	5.1	0.2	6.7	1.4	1.2
Pool 8	1,885	5	150	60	19	4.5	30.4	21.4	5.2	0.2	13.5	1.5	1.2
Pool 4	714	10	183	65	27	6.8	30.0	21.3	4.9	0.1	6.7	1.3	0.8

Field station	*N*	Current velocity (m/s)				Conductivity (µS/cm)				Water elevation (ft above sea level)			
		Min	Max	Mean	Std	Min	Max	Mean	Std	Min	Max	Mean	Std
Illinois River	786	0.02	0.67	0.09	0.10	12	1018	613	136	429	446	434	5
Unimpounded Upper Mississippi River	1,206	0.02	1.53	0.22	0.19	199	768	531	69	313	339	324	6
Pool 26	1,701	0.02	1.25	0.23	0.26	148	1031	443	71	420	439	425	4
Pool 13	1,546	0.02	1.07	0.17	0.20	232	545	402	44	583	601	588	3
Pool 8	1,885	0.02	1.40	0.17	0.17	114	569	397	65	630	643	633	2
Pool 4	714	0.02	0.95	0.14	0.16	35	755	393	121	667	679	670	3

Table 3. Amount of variation of each environmental variable explained within the six sampling reaches of the Upper Mississippi River System based on partial canonical correspondence analyses. Data were collected annually from 1993 to 2001 and variance shared among the variables was not examined.

	Secchi (cm)			Water temperature (°C)			Water depth (m)		
Field station	% variation	F-statistic	P-value	% variation	F-statistic	P -value	% variation	F-statistic	P -value
Illinois River	1.0	5.3	0.002	2.0	6.0	0.002	<1.0	3.0	0.016
Unimpounded Upper Mississippi River	3.0	6.9	0.001	3.0	7.4	0.001	15.0	36.8	0.001
Pool 26	4.0	16.1	0.002	3.0	12.2	0.002	15.0	55.8	0.002
Pool 13	2.0	5.6	0.002	1.0	2.7	0.002	2.0	6.2	0.002
Pool 8	4.0	6.8	0.002	<1	2.5	0.002	12.0	42.7	0.002
Pool 4	11.0	22.5	0.002	1.0	3.0	0.002	3.0	3.6	0.002

	Current velocity (m/s)			Conductivity (µS/cm)			Water elevation (ft above sea level)		
Field station	% variation	F-statistic	P-value	% variation	F-statistic	P -value	% variation	F-statistic	P -value
Illinois River	1.0	4.0	0.002	3.0	9.9	0.002	2.0	6.7	0.002
Unimpounded Upper Mississippi River	3.0	8.71	0.001	<1.0	2.0	0.006	6.0	14.0	0.001
Pool 26	6.0	22.5	0.002	1.0	4.8	0.002	2.0	9.4	0.002
Pool 13	11.0	28.1	0.002	<1.0	1.8	0.002	<1.0	2.4	0.002
Pool 8	9.0	20.0	0.002	1.0	3.9	0.002	2.0	5.6	0.002

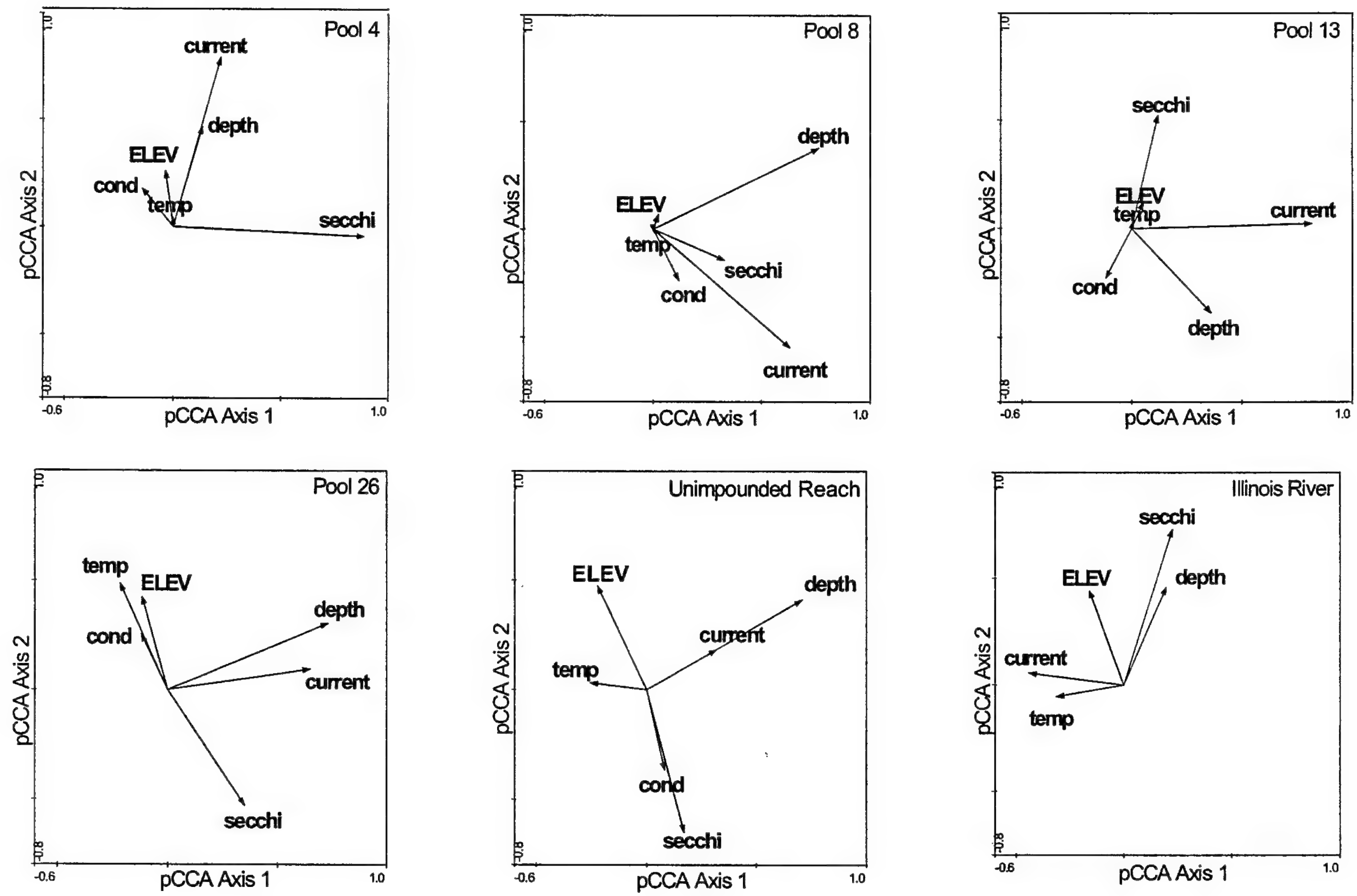


Figure 2. Partial canonical correspondence analysis (pCCA) of environmental gradients and species for the Upper Mississippi River System, given gear, year, and period. Eigenvalues were as follows: Pool 4 (Axis 1 eigenvalue = 0.115, Axis 2 eigenvalue = 0.069); Pool 8 (Axis 1 eigenvalue = 0.139, Axis 2 eigenvalue = 0.046); Pool 13 (Axis 1 eigenvalue = 0.107, Axis 2 eigenvalue = 0.028); Pool 26 (Axis 1 eigenvalue = 0.186, Axis 2 eigenvalue = 0.052); Unimpounded Reach (Axis 1 eigenvalue = 0.194, Axis 2 eigenvalue = 0.049); Illinois River (Axis 1 eigenvalue = 0.047, Axis 2 eigenvalue = 0.017).

Ordination—Temporal Shifts in Assemblages

Between 1993 and 2001, the fish assemblages of the UMRS were subjected to floods of varying magnitude, as well as the introduction of exotic species, such as silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*H. nobilis*; Chick and Pegg 2002). The effects of the 1993 flood seem to have resonated through 1994 and 1995, probably because it was an unusual summer flood and among the highest recorded floods throughout the system (Gutreuter et al. 1999; Figures 3 and 4). In the lower reaches of the UMRS, this was classified as a 500-year flood with record setting duration and discharge (Parrett et al. 1993). However, the extent of the influence of interannual variability on assemblage structure varied between age classes (i.e., YOY and adult) and among the study areas (Figures 3 and 4). For adults, sample years explained the most variation in the Unimpounded study area (12.2%; $F = 3.7$; $P = 0.0005$) followed by Pools 8 (11%; $F = 17.5$; $P = 0.002$) and 26 (11%; $F = 5.6$; $P = 0.0005$), Pools 4 (9%; $F = 2.9$; $P = 0.0005$) and 13 (9%; $F = 3.8$; $P = 0.005$), and the Illinois River study area (8%; $F = 12.2$; $P = 0.002$). For YOY assemblages, sample year explained the most variation in Pool 13 (50%; $F = 7.4$; $P = 0.0005$), followed by Pool 4 (34%; $F = 2.9$; $P = 0.0005$), Pool 8 (32%; $F = 15.1$; $P = 0.002$), the Unimpounded study area (27%; $F = 14.4$; $P = 0.002$), Pool 26 (19%; $F = 4.1$; $P = 0.0005$), and the Illinois River study area (13%; $F = 3.7$; $P = 0.0005$). Interannual variability appears to influence YOY assemblage structure in the UMR to a greater extent than adult assemblage structure, especially in the upper study areas. For both adult and YOY assemblages, patterns were not strong, but temporal variability was evident based on the separation of the sample years in ordination space (Figures 3 and 4). In Pool 26 and the Unimpounded reach, Axis 1 separated the years 1994, 1995, and 1996 from the other years indicating the adult assemblage present in the early years of sampling differed from the assemblage present in the later years in these lower UMR study areas (Figure 3). Within all study areas except the Unimpounded Reach, the YOY assemblage structure has shifted over time because Axis 1 separates the earlier sample years (1993–1998) from the later sample years (1999–2001; Figure 4). The underlying cause of the shift in abundance is unknown. Although some general patterns emerged, 9 years may not be enough time to identify the response of the fish assemblage to interannual variability within the system. Many species are long-lived and responses to changes in the system are not instantaneous and may not appear for several generations. Conversely, these findings may also suggest that temporal variability within the UMR may not affect assemblages as much as regional variability (e.g., localized variability within each reach) because assemblages and age classes did not respond to each year similarly within and among the study reaches.

Ordination—Assemblage/strata Relations by Reach

The physical habitats sampled by the LTRMP were separated in ordination space within all study areas based on fish abundance patterns; however, the amount of separation varied within and among the age classes and study areas (Figures 5 and 6). For adults, physical habitats explained the most variation in Pool 8 (23%; $F = 61.33$; $P = 0.002$), followed by Pool 4 (22%; $F = 19.1$; $P = 0.0005$), Pools 26 (19%; $F = 60.55$; $P = 0.002$) and 13 (19%: $F = 16.1$; $P = 0.0005$), Illinois River reach (12%; $F = 47.2$; $P = 0.002$), and the Unimpounded reach (3%; $F = 4.07$; $P = 0.002$). For YOY assemblages, physical habitats explained the most variation in Pool 8 (20%; $F = 12.3$; $P = 0.002$), Pool 26 (17%; $F = 17.8$; $P = 0.002$), Pool 13 (15%; $F = 4.3$; $P = 0.0005$), Pool 4 (10%; $F = 2.3$; $P = 0.017$), Illinois River reach (3%; $F = 3.4$; $P = 0.0005$), and the Unimpounded Reach (3%; $F = 2.4$; $P = 0.002$). The magnitude of association between abundance and particular physical habitat was also low for many species, which may indicate: (1) an unstable fauna represented by a few dominant generalists, suggesting that the UMRS is degraded and could be moving toward a system dominated by tolerant species (Kingsolving and Bain 1993), (2) physical habitat classes defined by the LTRMP are

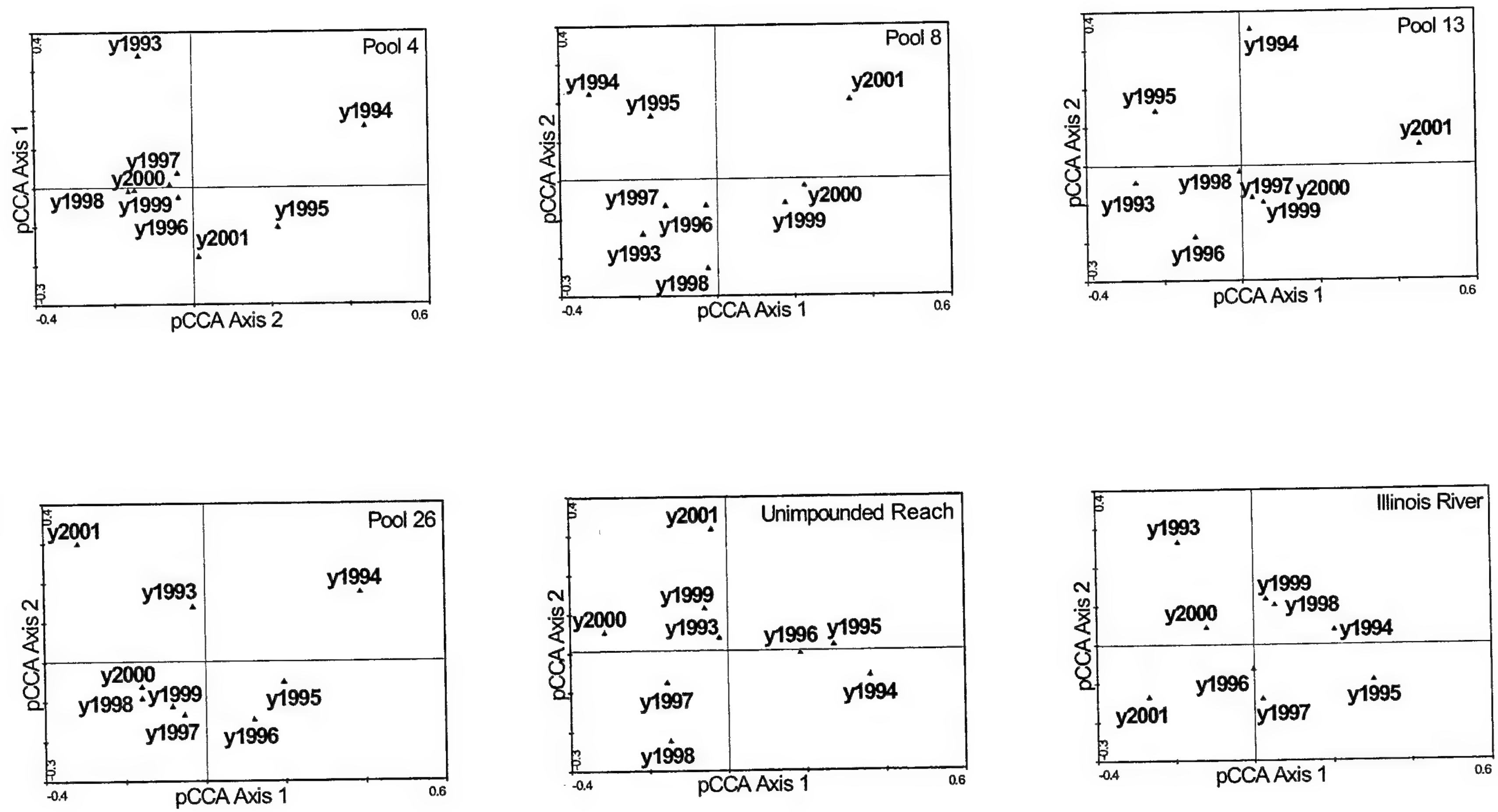


Figure 3. Partial canonical correspondence analysis (pCCA) of year and adult individuals for the Upper Mississippi River System, given gear, period, and physical habitats. Eigenvalues were as follows: Pool 4 (Axis 1 eigenvalue = 0.030, Axis 2 eigenvalue = 0.019); Pool 8 (Axis 1 eigenvalue = 0.040, Axis 2 eigenvalue = 0.022); Pool 13 (Axis 1 eigenvalue = 0.027, Axis 2 eigenvalue = 0.024); Pool 26 (Axis 1 eigenvalue = 0.045, Axis 2 eigenvalue = 0.024); Unimpounded Reach (Axis 1 eigenvalue = 0.045, Axis 2 eigenvalue = 0.018); Illinois River (Axis 1 eigenvalue = 0.028, Axis 2 eigenvalue = 0.014).

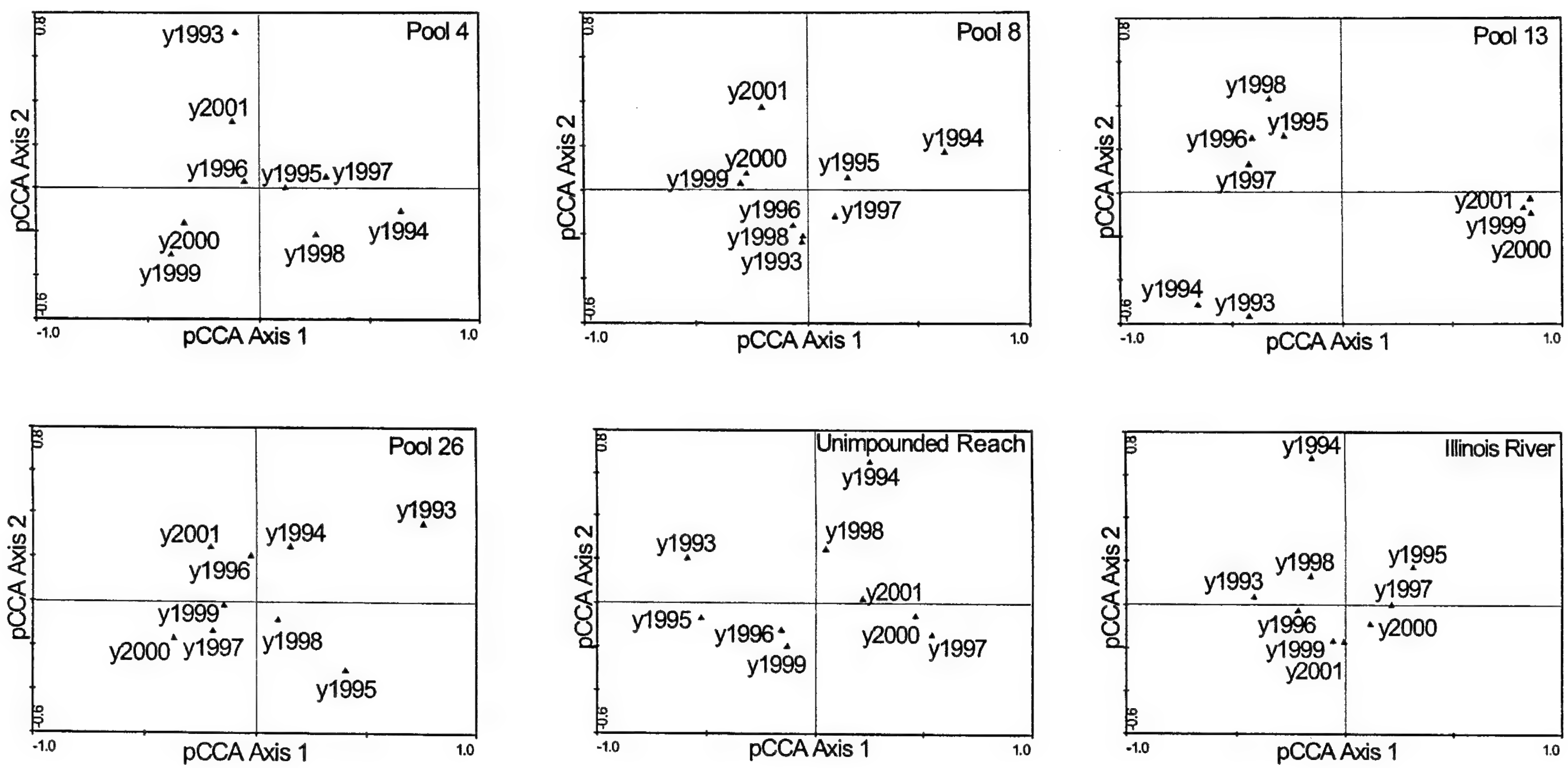


Figure 4. Partial canonical correspondence analysis (pCCA) of year and young-of-the-year individuals for the Upper Mississippi River System, given gear, period, and physical habitats. Eigenvalues were as follows: Pool 4 (Axis 1 eigenvalue = 0.123, Axis 2 eigenvalue = 0.064); Pool 8 (Axis 1 eigenvalue = 0.136, Axis 2 eigenvalue = 0.063); Pool 13 (Axis 1 eigenvalue = 0.281, Axis 2 eigenvalue = 0.085); Pool 26 (Axis 1 eigenvalue = 0.069, Axis 2 eigenvalue = 0.038); Unimpounded Reach (Axis 1 eigenvalue = 0.117, Axis 2 eigenvalue = 0.051); Illinois River (Axis 1 eigenvalue = 0.038, Axis 2 eigenvalue = 0.031).

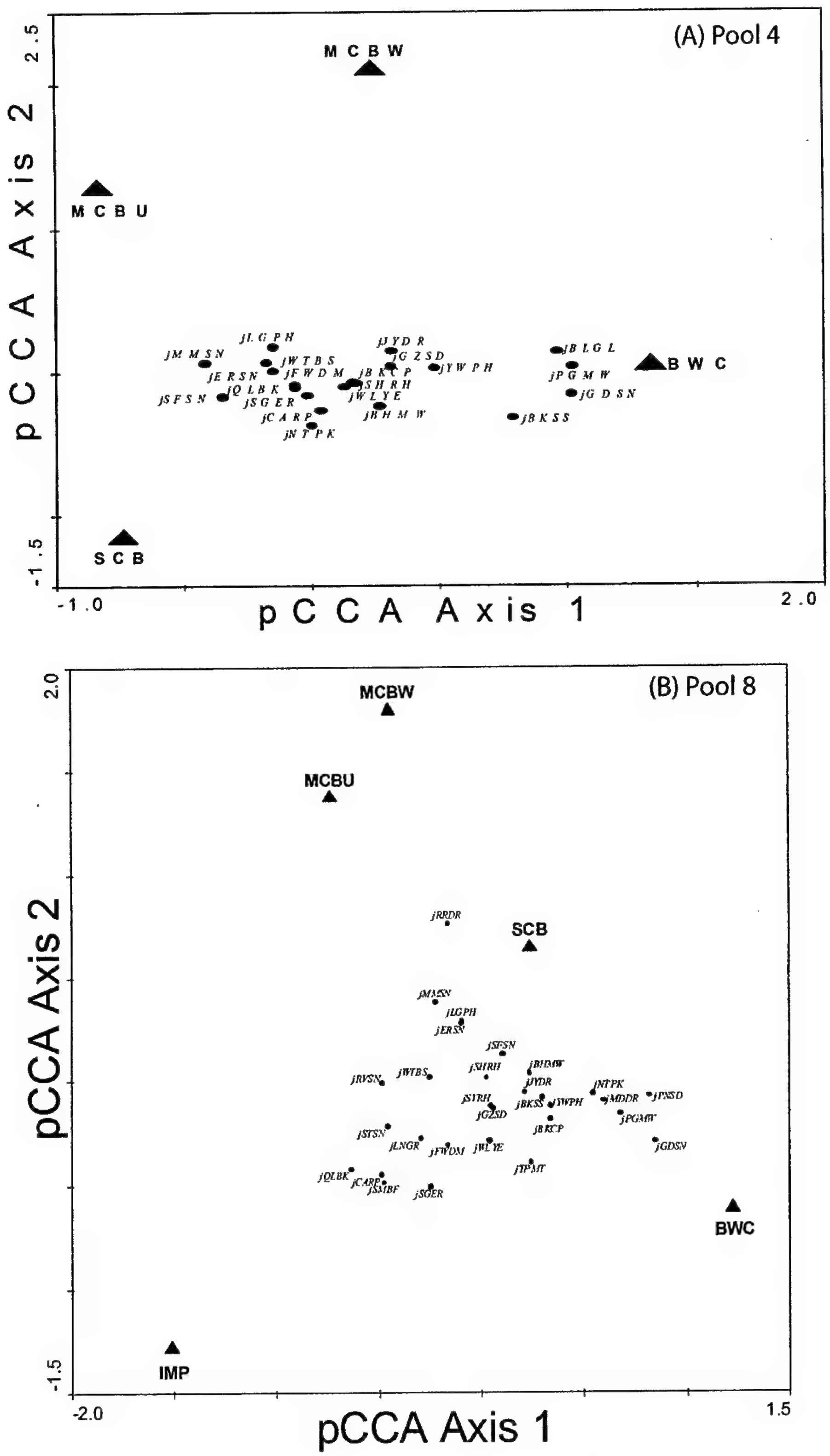
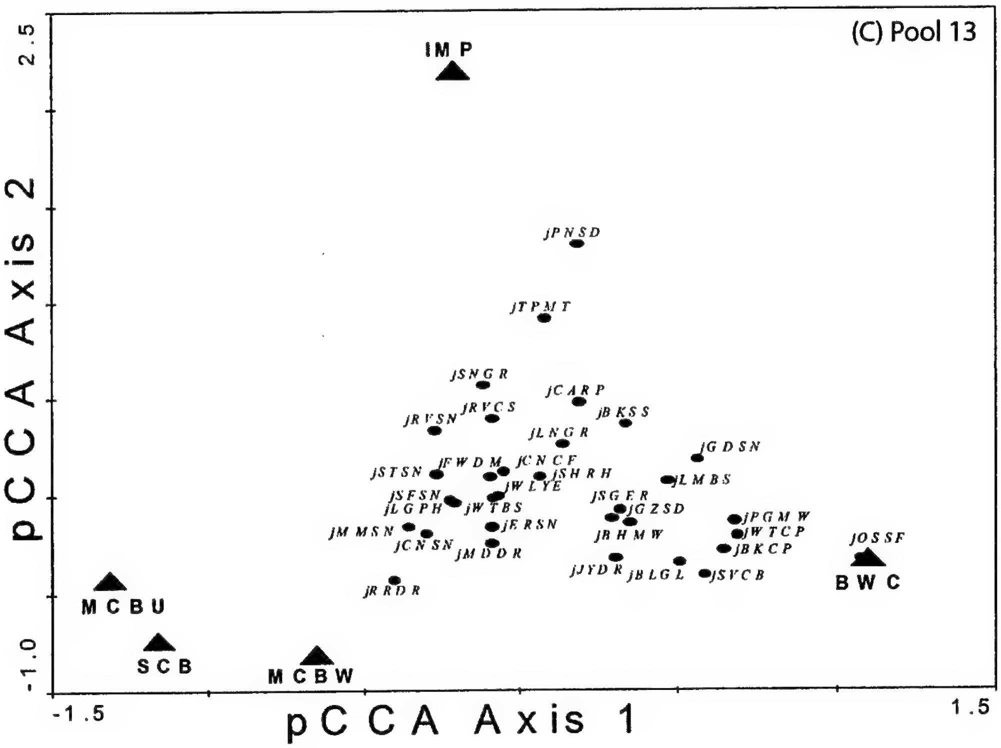


Figure 5. Partial canonical correspondence analysis (pCCA) of strata and young-of-the-year individuals for the Upper Mississippi River System, given period, gear, and year. (*A*) Species scores for abundant species from Pool 4 (Axis 1 eigenvalue = 0.080, Axis 2 eigenvalue = 0.012); (*B*) Pool 8 (Axis 1 eigenvalue = 0.092, Axis 2 eigenvalue = 0.054);



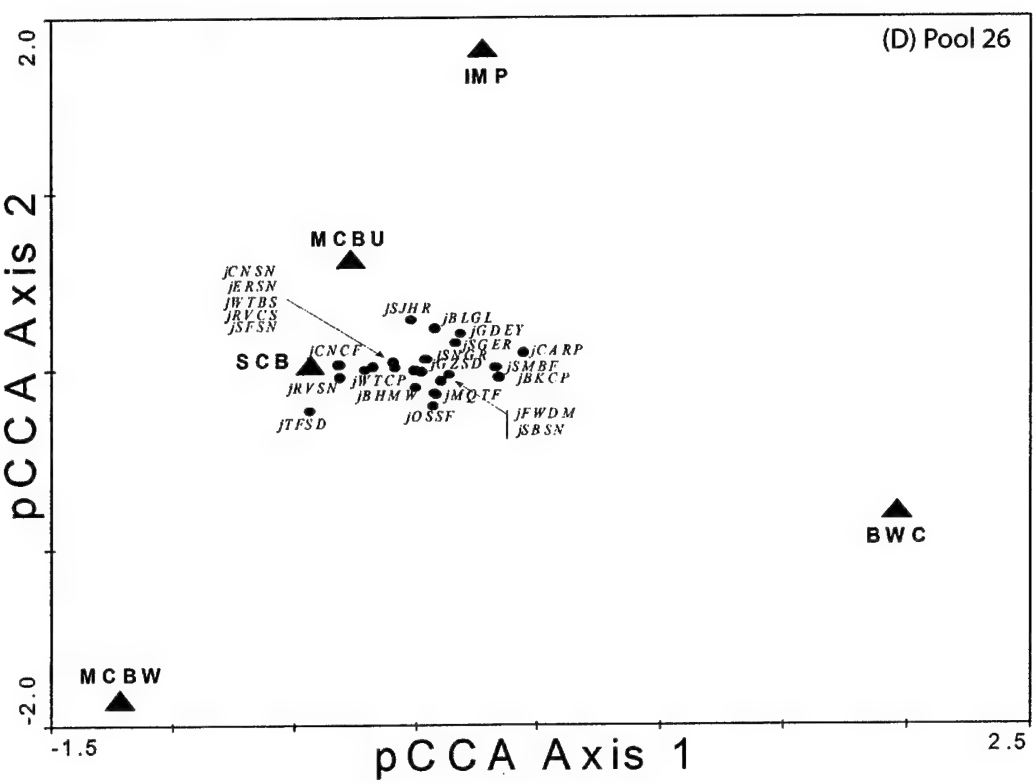


Figure 5. Continued. (*C*) Pool 13 (Axis 1 eigenvalue = 0.083, Axis 2 eigenvalue = 0.051); (*D*) Pool 26 (Axis 1 eigenvalue = 0.102, Axis 2 eigenvalue = 0.035);

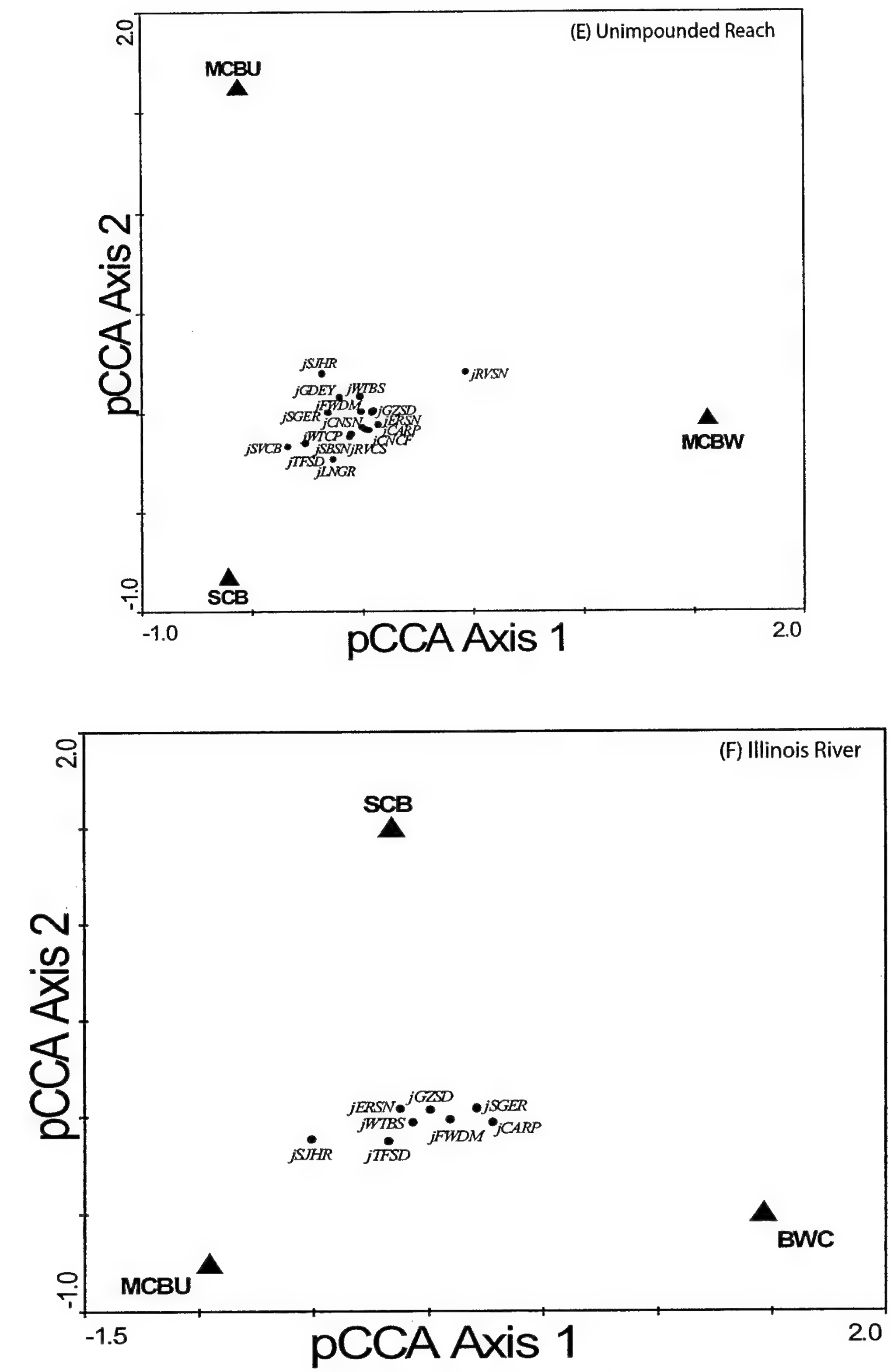


Figure 5. Continued. (*E*) Unimpounded Reach (Axis 1 eigenvalue = 0.008, Axis 2 eigenvalue = 0.010); (*F*) Illinois River (Axis 1 eigenvalue = 0.029, Axis 2 eigenvalue = 0.004). See Table 1 for species codes. Backwater contiguous (BWC), impounded (IMP), main channel border unstructured (MCBU), main channel border wing dam (MCBW), and side channel border (SCB).

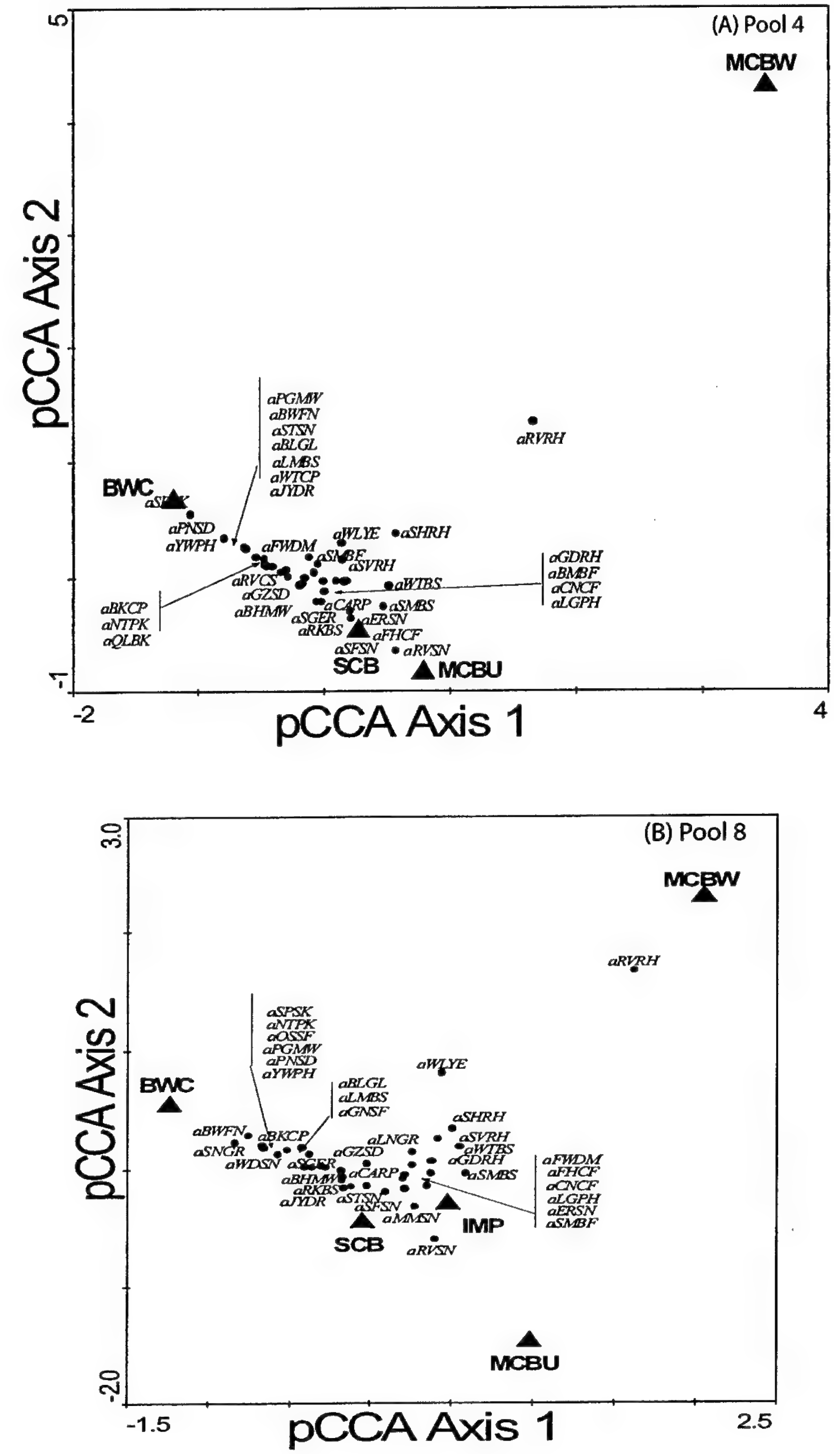
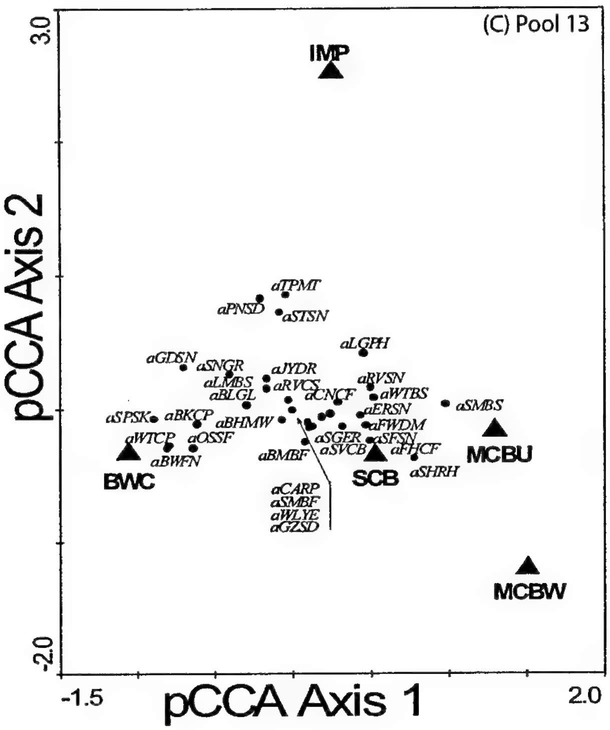
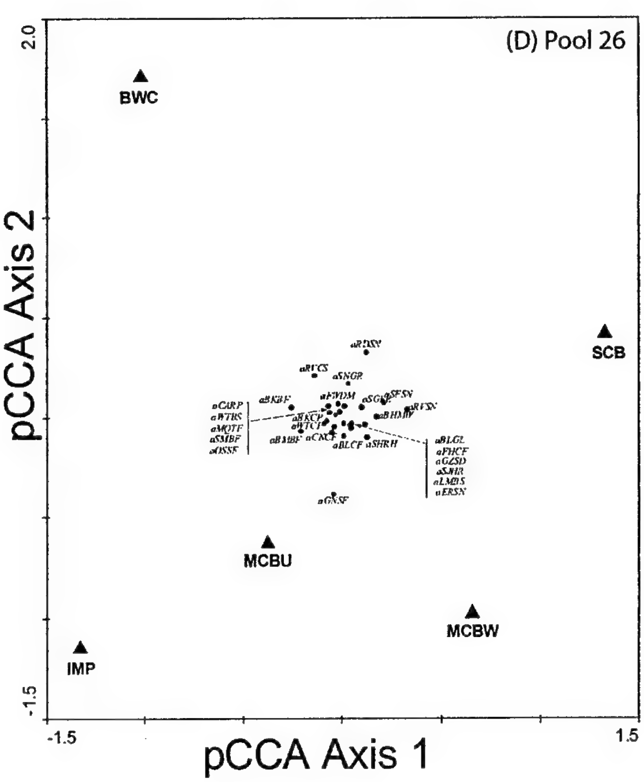


Figure 6. Partial canonical correspondence analysis (pCCA) of strata and adult individuals for the Upper Mississippi River System, given gear, period, and year. (*A*) Species scores for abundant species from Pool 4 (Axis 1 eigenvalue = 0.139, Axis 2 eigenvalue = 0.071); (*B*) Pool 8 (Axis 1 eigenvalue = 0.139, Axis 2 eigenvalue = 0.055); (*C*) Pool 13 (Axis 1 eigenvalue = 0.129, Axis 2 eigenvalue = 0.038); (*D*) Pool 26 (Axis 1 eigenvalue = 0.143, Axis 2 eigenvalue = 0.035); (*E*) Unimpounded Reach (Axis 1 eigenvalue = 0.019, Axis 2 eigenvalue = 0.014); (*F*) Illinois River (Axis 1 eigenvalue = 0.103, Axis 2 eigenvalue = 0.012). See Table 1 for species codes. Backwater contiguous (BWC), impounded (IMP), main channel border unstructured (MCBU), main channel border wing dam (MCBW), and side channel border (SCB).





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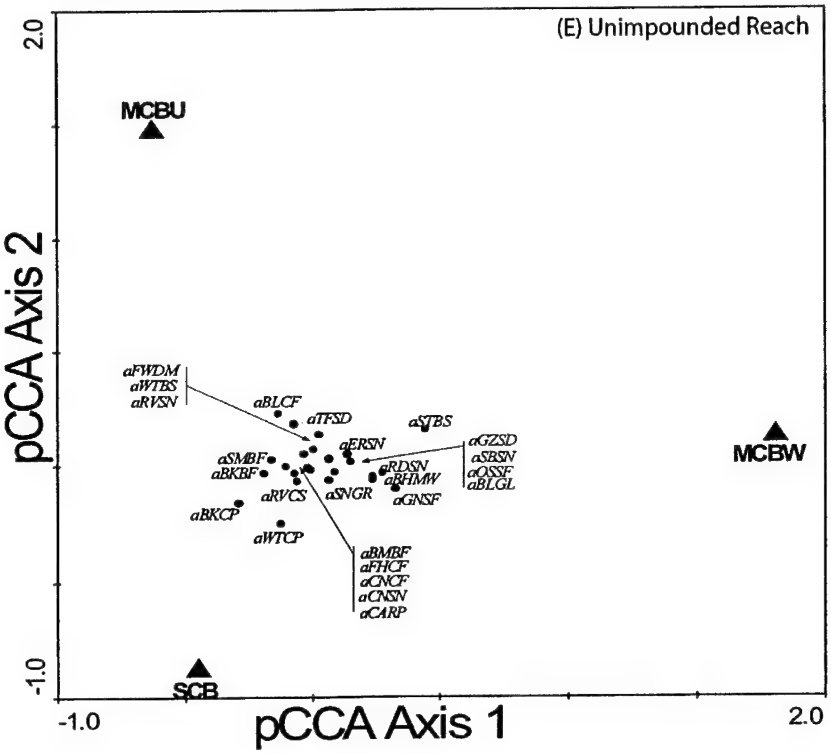

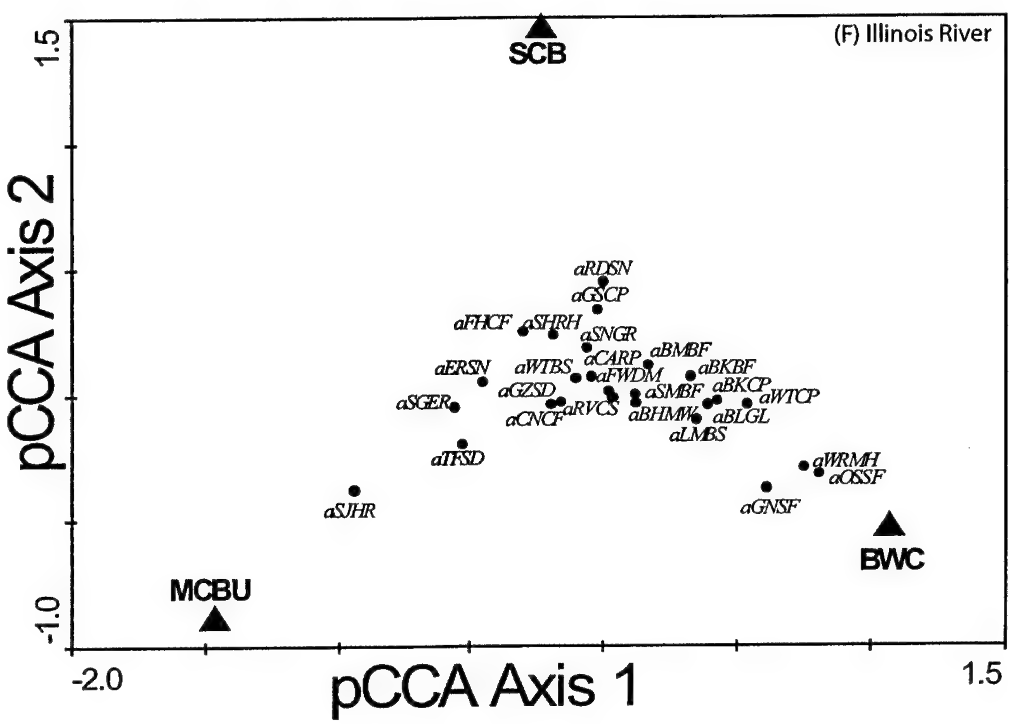

Figure 6. Continued.

poor predictors of assemblage patterns, or (3) environmental conditions within these physical habitats are similar enough over the course of a sampling season that our approach did not discriminate their effects well. Baker et al. (1991) and Barko et al. (2004*b*) also reported low associations between fish species and Mississippi River physical habitats; patterns often indicative of a tolerant fauna. We are unsure if the low associations in the Unimpounded and Illinois River study areas are because of reduced habitat heterogeneity or merely reflect the disproportionate number of habitats sampled within the reaches (Unimpounded and Illinois River = 3; Pools 4, 8, 13, and 26 = 5).

Ordination—Sampling Period

In all reaches, the amount of variation explained by sampling period was relatively low. Sampling period explained the most variation in the Unimpounded study area (9%; $F = 18.9$; $P = 0.002$), Pool 8 (9%; $F = 24.7$; $P = 0.002$), and Pool 13 (9%; $F = 11.7$; $P = 0.0005$), followed by Pool 4 (7%; $F = 11.9$; $P = 0.002$), Pool 26 (6%; $F = 16.4$; $P = 0.002$) and the Illinois River study area (6%; $F = 20.6$; $P = 0.002$). Although the amount of variation in fish abundance explained was low, Axis 1 separated sampling period 1 from sampling period 3 in all study areas, indicating that the assemblages present during these two periods were different (Figure 7). In Pools 4, 8, and 13 and along the same axis, the assemblage sampled in period 2 was more similar to the assemblage sampled in period 3 (because of their close proximity in ordination space) and sampling period 1 was the most unique based on assemblage structure (Figure 7). Conversely, in Pool 26, the Unimpounded and Illinois River study areas, the assemblage sampled in period 2 was more similar to the assemblage sampled in period 1; hence, the assemblage sampled in period 3 was the most unique. In all study areas, Axis 2 separated sampling period 2 from the other sampling periods. Therefore, although sampling period 2 grouped with one of the other sampling periods along Axis 1, the assemblage sampled during period 2 provides additional structure information that is different from that provided by sampling periods 1 and 3.

Conclusions and Recommendations

Our analyses identified several factors associated with differences in fish assemblage patterns within each of six LTRMP study areas. Based on our findings, we make the following programmatic recommendations:

1. The time series of LTRMP data is still relatively short and assessment of long-term trends in assemblage structure will require a longer time series. Our results suggest that some of the largest shifts in assemblage structure, particularly for YOY assemblages, were associated with flood years. However, the effects of floods on assemblage structure varied among the six study areas. The source of this variation is potentially related to how different sections of the river convey floodwaters and how accessible off-channel areas are to fishes during floods. Maintenance of standardized long-term monitoring data is necessary for arriving at a deeper understanding of how fish assemblages respond to the present day configuration of the UMRS, and how floods, acting across this physical template, affect the maintenance of diverse and persistent fish faunas. Such understanding will have direct applied and adaptive management benefits for managing the UMRS as a nationally significant system.

2. Whereas interannual factors, probably associated with flood responses, were important in explaining abundance patterns in the UMRS fish assemblages, spatial factors were generally found to be better predictors of differences in fish assemblages. This finding suggests that there is a strong spatial component in the way that UMRS fish assemblages are presently structured, and how these assemblages change over time. Additional research is needed to clarify how spatial factors influence assemblage structure.

3. Adult and YOY assemblage patterns differed in their response to environmental factors, interannual variability, and physical habitats. This suggests that future research

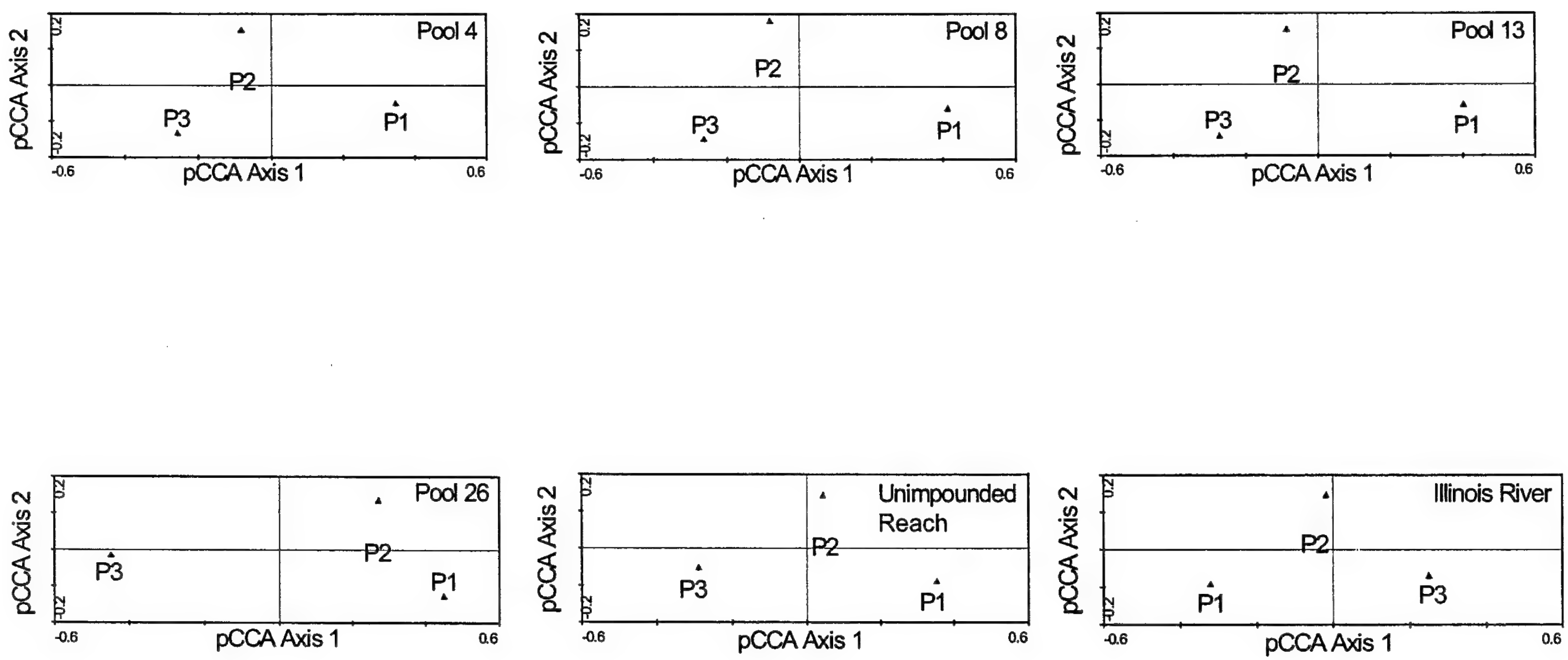

Figure 7. Partial canonical correspondence analysis (pCCA) of sampling periods 1 (P1), 2 (P2), and 3 (P3) for the Upper Mississippi River System, given gear, year, and physical habitats. Eigenvalues were as follows: Pool 4 (Axis 1 eigenvalue = 0.058, Axis 2 eigenvalue = 0.016); Pool 8 (Axis 1 eigenvalue = 0.071, Axis 2 eigenvalue = 0.020); Pool 13 (Axis 1 eigenvalue = 0.069, Axis 2 eigenvalue = 0.017); Pool 26 (Axis 1 eigenvalue = 0.045, Axis 2 eigenvalue = 0.017); Unimpounded Reach (Axis 1 eigenvalue = 0.077, Axis 2 eigenvalue = 0.016); Illinois River (Axis 1 eigenvalue = 0.051, Axis 2 eigenvalue = 0.012).

on UMRS fish assemblage dynamics should differentiate among life stages.

4. Program partners should use the results of this research and other recently completed research to develop and prioritize additional research topics. Many of the analyses completed over the last year, whereas quantitatively intense, are largely qualitative assessments.

5. Continued quantitative monitoring of the UMR fish assemblage will allow us to identify trends not visible with the 10 years of data presently available. Specifically, (1) will assemblages redistribute themselves within the river and reaches based on future habitat alterations and disturbances (e.g., increased navigation, climate change, altered hydrology, invasive species, habitat restoration, etc.); (2) will assemblages in impounded sections become skewed towards a lacusterine assemblage rather than a riverine assemblage; (3) how will species and assemblages respond to invasive introductions; (4) what environmental variables should the LTRMP be measuring in addition to the present suite to better explain fish assemblage patterns; and (5) does the UMR fish assemblage demonstrate persistence or stability over longer time frames and do different areas of the UMRS demonstrate different stability thresholds?

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13. ABSTRACT (Maximum 200 words)

We investigated differences in adult and young-of-the-year (YOY) fishes within each of the six Long Term Resource Monitoring Program study areas, using monitoring data from 1993 to 2001. Our objective was to investigate the relative roles of seasonal, annual, in situ, and physical habitat factors in explaining assemblage structure patterns within the Long Term Resource Monitoring Program study areas. Adult and YOY assemblage structure within each reach was dominated by one to three numerically abundant species. The percent of the total abundance for which these species accounted was 10–88% and varied among age classes and study areas. Physical habitat classes were only weakly associated with differences in fish assemblage patterns within each study area. The amount of variation in fish abundance explained by physical habitats varied among the reaches. Differences among physical habitat classes accounted for 3–23% of the variation in the adult fish assemblage and for 3–20% of the difference in the YOY fish assemblage within each reach of our study area. Factors associated with interannual differences in environmental conditions were strongly correlated to patterns in assemblage structure within each of the six study areas. This was particularly true for YOY assemblages. Such a result would not have been attainable without long-term standardized data. Little is known regarding YOY assemblage patterns and dynamics in large river systems and long-term data sets are vital for continued investigation. The influence of environmental gradients on fish assemblage structure varied among the six study areas and explained 9–31% of the variation in assemblage structure. In the northern four reaches, water velocity was one of the primary factors associated with differences in fish assemblage structure. In the Unimpounded Reach (Upper Mississippi River) and Illinois River study areas, river elevation was one of the primary factors associated with differences in assemblage structure. Depth of gear deployment was influential in explaining differences in assemblage structure patterns in all reaches except the Upper Mississippi River Pool 4 and the Illinois River study areas. In all study areas, the amount of variation in fish abundance patterns explained by sampling period was relatively low. However, assemblage structure differed among sampling periods. In the northern reaches, sampling periods 2 and 3 were the most similar.

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